

Recycling and Beneficial Reuse



APPENDIX E1
WES MATERIAL CHARACTERISTICS

EXECUTIVE SUMMARY

Dredged material is the result of soil erosion and surface runoff from terrestrial environments. Soil particles along with other materials in runoff finds their way to the bottom of waterways. These soil particles become sediment that eventually needs to be removed from the waterways to maintain navigation. The U.S. Army Corps of Engineers (USACE) is responsible for maintaining navigable waterways and annually dredges approximately 308 million m³ (400 million cubic yards) of sediment. Finding places to put the dredged material is becoming harder and harder. Many confined disposal sites have been completely filled. The USACE is seeking solutions to this situation. Likewise, sewage sludge can no longer be disposed in the ocean and is piling up on land. To resolve the accumulation of sewage sludge, the USEPA has recently issued 40 CFR Part 503 regulations that promote the reuse of biosolids derived from conditioned sludge.

To address both the excess of dredged material and sewage sludge, the Waterways Experiment Station (WES) Environmental Laboratory began to evaluate the potential for manufacturing an artificial soil from dredged material and organic wastes. Cooperative Research and Development Agreements (CRDAs) were established with commercial companies to develop the technology for manufacturing soil from dredged material. The technology would allow the development of a fertile soils/manufactured soil product that can be used in a beneficial manner, allow the USACE to empty confined dredged material disposal sites that are full and recycle the nation's waste materials in an environmentally sound manner.

Bioassays (seed germination and plant growth) were used to evaluate the

feasibility of manufacturing soil using dredged material from Toledo Harbor Cell 1 disposal facility. Bioassays included blends of dredged material, cellulose, and biosolids.

Seed Germination Bioassays: Tomato, marigold, vinca, and ryegrass were tested following procedures developed by a nationally known bagged soil products company. Percent seed germination was highest in blend 2 consisting of dredged material from Toledo Harbor Cell 1, cellulose, and biosolids. Even though percent germination was highest in blend 2, ryegrass percent germination was highest in blends 3 and 1. Results after 21 days paralleled results obtained in the 14-day germination test. The additional time did, however, enhance percent seed germination.

Extended Growth Test Using Manufactured Soil Blends: A seven-week plant growth bioassay was conducted using the same experimental design as the seed germination study. Visual observation of leaf color, size, and shape, and total aboveground biomass was used to evaluate the influence of the different manufactured soil blends on plant growth. Results showed that the highest biomass was obtained from blend 4. Evaluation of the plant aboveground biomass data also showed that blend 4 produced plant growth comparable to the fertile reference control (commercial bagged soil product). Therefore, blend 4 consisting of dredged material from Toledo Harbor Cell 1 disposal facility blended with cellulose and biosolids looks very promising as a manufactured soil product.

PREFACE

This report describes work done by the U.S. Army Corps of Engineers Waterways Experiment Station (USACE WES), Vicksburg, MS. This study was sponsored by the U. S. Army Corps of Engineers, Buffalo District, Buffalo, New York, under civil works reimbursable project.

The study was conducted and the report prepared by Drs. Thomas C. Sturgis and Charles R. Lee, fate and Effects Branch (FEB), Environmental Processes and Effects Division (EPED), Environmental Laboratory (EL). Mr. Henry C. Banks, Jr., ASCi provided assistance in preparing and conducting the laboratory/greenhouse bioassay tests.

The study was conducted under the general supervision of Richard E. Price, Chief, EPED, and Dr. John Harrison, Director, EL.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Robin R. Cababa.

This report should be cited as follows:

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TABLE OF CONTENTS

INTRODUCTION	
Background.....	1
Purpose and Scope.....	2
MATERIALS AND METHODS.....	3
Sediment Collection.....	3
Manufactured Soil Bioassay Tests.....	9
Seed Germination and Plant Growth Tests.....	9
STATISTICAL ANALYSIS.....	15
RESULTS AND DISCUSSION.....	16
Sediment Characterization.....	16
Seed Germination Bioassay Test.....	16
Toledo Harbor Dredged Material Cell 1.....	16
Plant Growth Bioassay Test.....	20
Toledo Harbor Dredged Material Cell 1.....	20
CONCLUSIONS.....	27
RECOMMENDATIONS.....	27
LITERATURE CITED.....	28
APPENDIX A: Summary of results from Scott and Sons Screening test.....	29

LIST OF FIGURES

FIGURE

1. Diagram showing locations of all 3 sites within Cell 1 CDF.....	4
2. Overall view of site 1 (heavily vegetated).....	5
3. Toledo Harbor Cell 1 CDF - site 1 (20 June 1994).....	5
4. Site 2 midway across Cell 1 CDF (21 June 1994).....	6
5. Site 3 located near weir (21 June 1994).....	6
6. Sediment sample collected at 12' depth.....	7
7. Sediment sampling using soil auger.....	7
8. Soil auger with extension rod and handle.....	7
9. Bulk sediment samples (0-3 ft depth) collected and being placed in bain marie buckets and cooler for shipping (July 1995).....	7
10. Inundation of site 2 (July 1995).....	8
11. Inundation of site 3 located near weir (July 1995).....	8
12. Overall view of the Toledo Harbor seed germination test.....	18
13. Overall view of the Toledo Harbor dredged material plant growth test at 7 weeks.....	21
14. Total above-ground plant biomass from various Toledo harbor material mixtures.....	22
15. Tomato plants in the various Toledo Harbor dredged material mixtures at 7 weeks.....	23
16. Marigold plants in the various Toledo Harbor dredged material mixtures at 7 weeks.....	25
17. Ryegrass plants in the various Toledo Harbor dredged material mixtures at 7 weeks.....	25
18. Vinca plants in the various Toledo Harbor dredged material mixtures at 7 weeks.....	26

LIST OF TABLES

TABLE

1. Toledo Harbor CDF Cell 1 pesticide concentrations 1994-1995.....	10
2. Toledo Harbor CDF Cell 1 PAH concentrations 1994-1995.....	11
3. Toledo Harbor CDF Cell 1 PCB concentrations 1994-1995.....	11
4. Toledo Harbor CDF Cell 1 metal concentrations 1994-1995.....	12
5. Toledo Harbor manufactured soil test experimental design.....	14
6. Predicted metal concentrations in blend 4 using 0-3' surface layer of dredged material from Toledo Harbor Cell 1.....	17
7. Soil fertility analysis and physical characterization of Blend 4 consisting of dredged material from cell 1.....	17
8. Percent seed germination from the Toledo Harbor dredged material manufactured soil test.....	24
9. Above-ground biomass from the Toledo Harbor dredged material manufactured soil test.....	24

INTRODUCTION

Background

The U. S. Army Corps of Engineers Buffalo District under authority of Code of Federal Regulations for navigation and navigable waters, 33 CFR 337.9 (Part 200 to the end), is responsible for identifying and developing dredged material disposal management strategies for long-term needs for Toledo Harbor, OH and to implement the National Environmental Policy Act 33 CFR 233 and 40 CFR 1501.7, to determine the scope and significance of issues related to proposed actions. This long-term Management Strategy (LTMS) is also conducted under authority provided by Section 356 of the Water Resources Development Act of 1992 (WRDA 92), which directed the development of a comprehensive sediment management strategy for the Maumee River, Toledo, OH.

To develop an LTMS for Toledo Harbor, a five-year Memorandum of Agreement (MOA) was signed in 1986 by the U.S. Army Corps of Engineers, the Ohio Environmental Protection Agency, the Toledo Metropolitan Area Council of Government, the Toledo-Lucas County Port Authority, and the City of Toledo.

The LTMS had five phases listed below:

Phase 1. Evaluate Existing Management Options

Phase 2. Formulate Alternatives Plans

Phase 3. Preliminary Analysis of Alternatives, Recommend for
Approval and Implementation, an Action Plan having an
Interim Plan as a component

Phase 4. Implement the LTMS that includes execution of the
Interim Plan

Phase 5. Implementation, Periodic Review, and Update of the LTMS

Phases 1, 2 and 3 have been completed and an Action Plan containing an Interim Plan has been recommended. One alternative recommended in the Action Plan is manufactured soil/beneficial reuse of Toledo Harbor dredged material. The Port Authority was given the lead to develop this alternative as NU-Soil for Island 18 confined disposal facility. The U. S. Army Corps of Engineers Waterways Experiment Station was asked to develop another form of manufactured soil with dredged material from Cell 1 confined disposal facility for the bagged soil and landscaping industries using its cooperative research and development agreements (CRDAs) with commercial companies who are interested in using Toledo Harbor dredged material as an ingredient for their manufactured soil products. For example, Scott & Sons Company has a requirement for 4 million cu yd of silt each year for their bagged soil product. The WES CRDA allows WES and Scotts Company to screen suitable dredged material for use in bagged soil products. The CRDAs will enable manufactured soil technology to be developed at USACE confined disposal sites. CRDAs established or are pending* are listed below:

<u>Participating Company</u>	<u>Aspect of Manufactured Soil</u>
Scott & Sons Company*	Bagged soil products
Terraforms	Formulation and blending equipment
N-Viro International	Reconditioned Biosolids from Sewage Sludge

Purpose and Scope

The purpose of this report is to present the results of screening tests conducted by Scott & Sons Company at its research facility in Marysville, OH and additional bioassay tests performed at WES. These tests were the first

such screening tests of dredged material from Toledo Harbor Cell 1 confined disposal facility and therefore were to indicate the feasibility of using the dredged material for manufactured soil products. Limited characterization of the dredged material was also obtained. The best formulation of dredged material, sawdust and N-Viro was to be determined and recommended for field demonstration at Toledo, OH.

MATERIALS AND METHODS

Sediment Collection

Samples of dredged material used in this study were collected from Cell 1 (site 1) on 20-21 June 1994 and on 19 July 1995 (Figures 1, 2, and 3). Sites 2 and 3 also found within Cell 1 were only collected in June 1994 (Figures 4 and 5). Core sediment samples were collected using a 4-inch diameter auger with a 15-ft extension rod. The extension rod allowed sediment samples to be taken down to a depth of 15 ft (Figures 6, 7, 8, and 9). Sediment samples were collected in June 1994 at depths of 0-4 ft, 4-8 ft and 8-12 ft. However, sediment samples collected in July 1995 were at intervals of 0-3 ft, 3-6 ft, 6-9 ft, and 9-12 ft. Sediment samples were collected, placed in 1-liter glass jars and stored in a 32-quart cooler and then transported to the WES. Upon arrival at WES, the sediment samples were stored at 4°C, and later prepared for chemical characterization (Tables 1, 2, 3 and 4). Wet conditions at sites 2 and 3 precluded sediment sample collection in 1995 (Figures 10 and 11). Large bulk samples of dredged material from site 1, collected at the 0-3 ft depth, were collected in 1995 and transported to Scott and Sons Company at Marysville, OH and the WES. Scott and Sons Company used this material to conduct their screening test for an evaluation of raw

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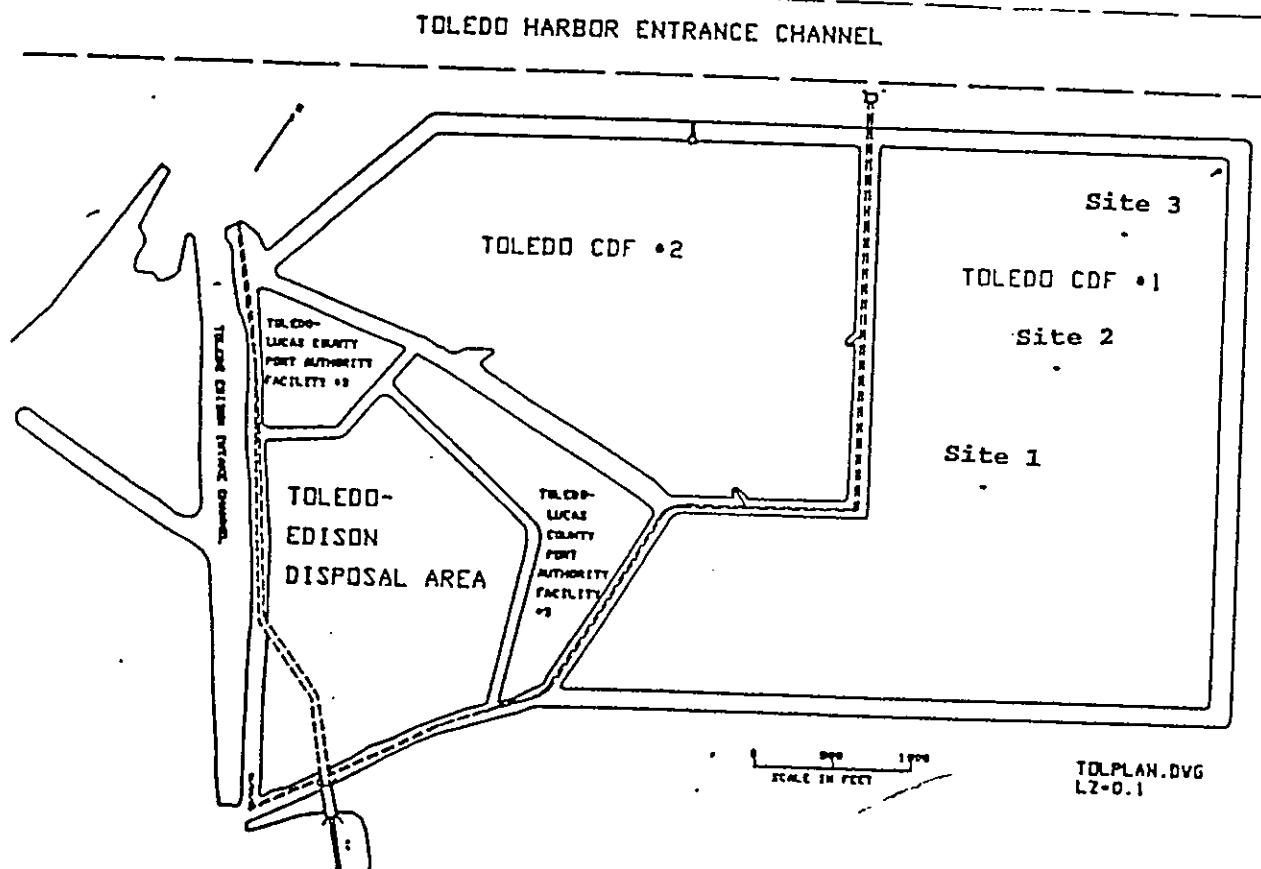


Figure 1. Diagram showing locations of all 3 sites within Cell 1 CDF.



Figure 2. Overall view of site 1 (heavily vegetated).



Figure 3. Toledo Harbor Cell 1 CDF - site 1 (20 June 1994).

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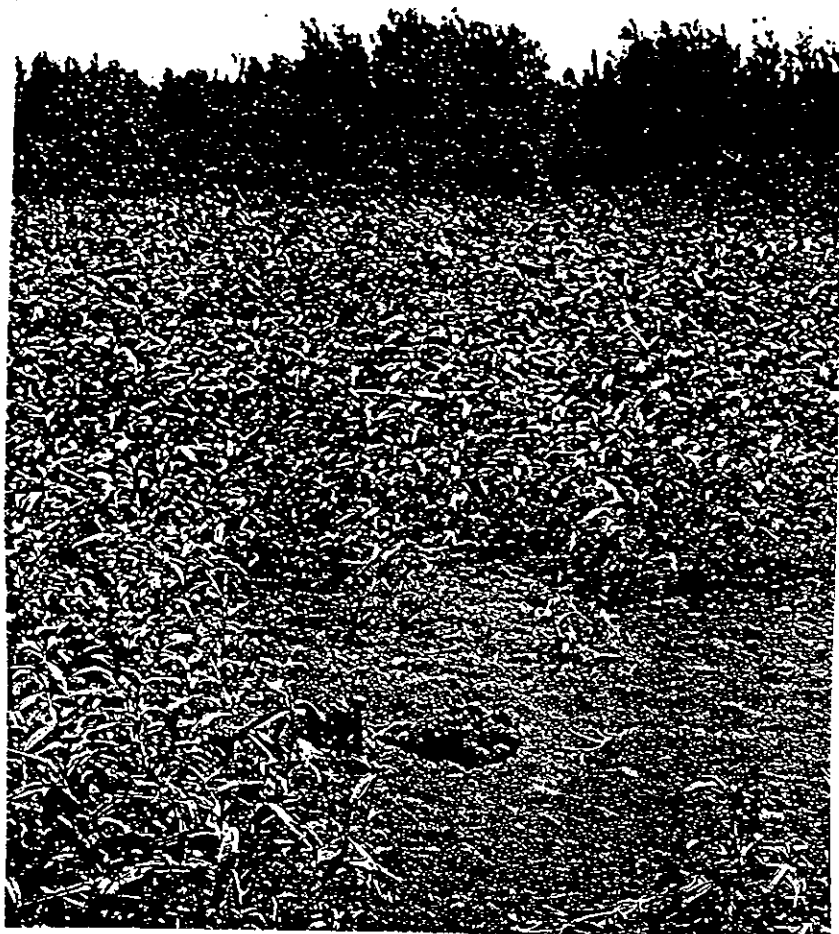


Figure 4. Site 2 located midway across Cell 1 CDF (21 June 1994).



Figure 5. Site 3 located near weir (21 June 1994).



Figure 6. Sediment sample being collected at 12' depth.

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Figure 7. Sediment sampling using soil auger.

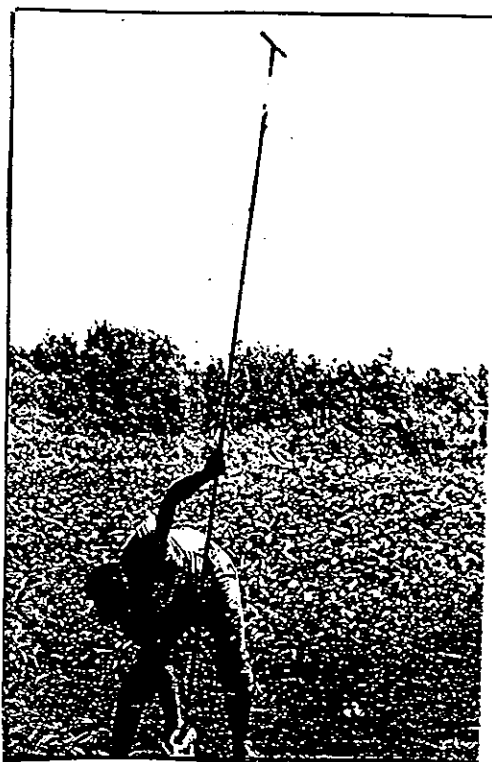


Figure 8. Soil auger with extension rod and handle.

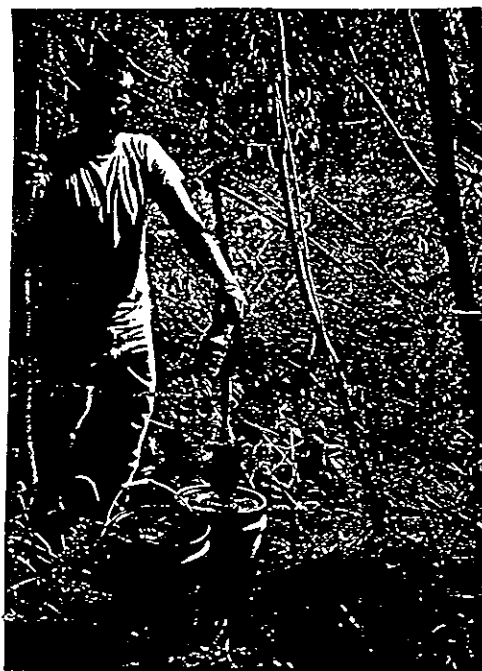


Figure 9. Bulk sediment samples collected and being placed in bain marine buckets and cooler.



Figure 10. Inundation of site 2 (July 1995).



Figure 11. Inundation of site 3 located near weir (July 1995).

Manufactured Soil Bioassay Tests

Seed Germination and Plant Growth Tests

Bioassay tests (seed germination and plant growth) using the procedures of a national bagged soil product Company were used to evaluate the feasibility of manufacturing soil from dredged material from Cell 1 for beneficial use for landscaping and topsoil. These tests included various blends of dredged material, cellulose, and biosolids. Through cooperative research and development agreements with Scott and Sons Company and with N-VIRO International, a new N-VIRO product with a pH of 7.0, was specifically produced for Toledo Harbor dredged material. A specific blend was prepared by placing the appropriate volume percentages of cellulose and biosolids in a V-mixer and mixing for 5 minutes. Toledo Harbor dredged material from cell 1 was then added and mixed an additional 5 minutes. This process was repeated until all mixtures were prepared. The volume percentage of dredged material added to the various blends was in the order of: blend 1 > blend 4 > blend 3 > blend 2 > blend 5 (fertile reference control).

Tomato, vinca, marigold, and ryegrass (four annual plant species) were grown from seed in the various blends to evaluate seed germination and plant growth. These plants are sensitive to salt, metals, nutrients imbalances and indicate a wide spectrum of upland plants. Tomato, marigold, and vinca seeds were obtained from Ball Seed Co., Chicago, Illinois and shipped to WES. Ryegrass seed was purchased from Warrenton Farms and Garden, Vicksburg, Mississippi.

Table 1. Toledo Harbor CDF Cell 1 Pesticides Concentrations 1994-1995 (mg/kg).

Parameters	94		95		94		95		94		95		94		94		94		94	
	Site 1	Site 1	Site 1	Site 1	Site 1	Site 1	Site 1	Site 1	Site 1	Site 1	Site 1	Site 1	Site 2	Site 2	Site 2	Site 2	Site 2	Site 2	Site 3	Site 3
	0'-4'	0'-3'	4'-8'	4'-8'	3'-6'	3'-6'	6'-9'	8'-12'	8'-12'	9'-12'	9'-12'	9'-12'	0'-4'	0'-4'	4'-8'	4'-8'	8'-12'	8'-12'	0'-4'	4'-8'
ALDRIN	<0.0019	<0.0019	<0.0019	<0.0019	<0.0018	<0.0018	<0.0018	<0.0018	<0.0017	<0.0018	<0.0018	<0.0018	0.0039	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075
A-BHC	<0.0014	<0.0014	<0.0014	<0.0014	<0.0014	<0.0014	<0.0014	<0.0014	<0.0013	<0.0013	<0.0013	<0.0013	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075
B-BHC	<0.0029	<0.0027	<0.0030	<0.0027	<0.0027	<0.0027	<0.0028	<0.0028	<0.0026	<0.0027	<0.0027	<0.0027	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075
G-BHC	<0.0019	<0.0019	<0.0019	<0.0019	<0.0018	<0.0018	<0.0018	<0.0018	<0.0017	<0.0018	<0.0018	<0.0018	0.0013	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0014
D-BHC	<0.00044	<0.00043	<0.0045	<0.0041	<0.0041	<0.0041	<0.0042	<0.0042	<0.0042	<0.0042	<0.0040	<0.0040	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075
PPDD	0.0041	0.0041	0.0078	0.0067	0.0067	0.0067	0.0081	0.0078	0.0078	0.0084	0.0084	0.0084	0.0035	0.0058	0.0058	0.0058	0.0082	0.0082	0.0038	0.0034
PPDE	0.0063	0.0064	0.0069	0.0069	0.0069	0.0069	0.0068	0.0068	0.0059	0.0064	0.0064	0.0064	0.0062	0.0069	0.0069	0.0069	0.0070	0.0070	0.0054	0.0047
PPDT	0.013	0.012	0.017	0.018	0.018	0.018	0.028	0.013	0.013	0.016	0.016	0.016	0.0023	0.0037	0.0037	0.0037	0.0038	0.0038	0.0026	0.0025
HPTCL	<0.0014	<0.0014	<0.0015	<0.0014	<0.0014	<0.0014	<0.0014	<0.0013	<0.0013	<0.0013	<0.0013	<0.0013	<0.011	<0.011	<0.011	<0.011	0.0032	0.0032	<0.011	0.0011
DIELDRIN	<0.00096	<0.00094	<0.00098	<0.00098	<0.00098	<0.00098	0.0059	<0.0087	<0.0087	<0.0089	<0.0089	<0.0089	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075
ENDO I	<0.0067	<0.0065	<0.0068	<0.0063	<0.0063	<0.0063	<0.0065	<0.0061	<0.0061	<0.0062	<0.0062	<0.0062	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075
ENDO II	<0.0019	<0.0019	<0.0019	<0.0018	<0.0018	<0.0018	<0.0018	<0.0017	<0.0017	<0.0018	<0.0018	<0.0018	<0.015	<0.015	<0.015	<0.015	<0.0099	<0.015	<0.015	<0.015
ENDOSU	<0.032	<0.031	<0.0033	<0.030	<0.030	<0.030	<0.031	<0.029	<0.029	<0.030	<0.030	<0.030	<0.015	<0.015	<0.015	<0.015	0.00099	<0.015	<0.015	<0.015
ENDRIN	0.0026	0.0022	0.0037	0.0051	0.0051	0.0051	0.0030	0.0034	0.0034	0.0033	0.0033	0.0033	0.0047	<0.023	<0.023	<0.023	<0.023	<0.023	0.0040	0.0038
ENDALD	<0.011	<0.011	0.0020	<0.010	<0.010	<0.010	0.0021	0.0016	0.0016	0.0018	0.0018	0.0018	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
HPTCLE	<0.039	<0.038	<0.040	<0.037	<0.037	<0.037	<0.038	<0.036	<0.036	<0.036	<0.036	<0.036	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075
METOXYCL	<0.084	<0.083	<0.086	<0.079	<0.079	<0.079	<0.081	<0.077	<0.077	<0.078	<0.078	<0.078	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075
CLORDANE	<0.0067	<0.0065	<0.0068	<0.0063	<0.0063	<0.0063	<0.0065	<0.0061	<0.0061	<0.0062	<0.0062	<0.0062	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075	<0.0075
TOXAPHEN	<0.11	<0.11	<0.12	<0.11	<0.11	<0.11	<0.11	<0.10	<0.10	<0.11	<0.11	<0.11	<0.015	<0.015	<0.015	<0.015	<0.15	<0.15	<0.15	<0.15

Table 2. Toledo Harbor CDF Cell 1 PAH Concentrations 1994-1995 (mk/kg)

Parameters	94		95		94		95		94		94		94	
	Site 1 0'-4'	Site 1 0'-3'	Site 1 3'-6'	Site 1 6'-9'	Site 1 8'-12'	Site 1 9'-12'	Site 2 0'-4'	Site 2 4'-8'	Site 2 8'-12'	Site 2 0'-4'	Site 2 4'-8'	Site 3 0'-4'	Site 3 4'-8'	
NAPHTH	0.054	0.044	0.13	0.21	0.16	0.24	0.23	0.054	0.11	0.11	0.067	0.075		
ACENAY	<0.48	<0.48	<0.50	<0.46	<0.47	<0.44	<0.44	<0.47	<0.47	<0.44	<0.49	<0.44		
ACENAP	<0.48	<0.48	0.051	0.050	<0.47	0.044	0.035	<0.47	<0.47	<0.44	<0.49	<0.44		
FLOURE	0.031	0.026	0.096	0.093	0.048	0.079	0.072	<0.47	<0.47	0.053	<0.49	<0.44		
PHENAN	0.22	0.21	0.52	0.60	0.36	0.40	0.36	0.21	0.30	0.27	0.19	0.22		
ANTRAC	0.046	0.040	0.19	0.16	0.087	0.13	0.10	0.047	0.065	0.073	0.041	0.059		
FLANTHE	0.29	0.31	0.77	0.78	0.42	0.70	0.52	0.37	0.39	0.43	0.32	0.34		
PYRENE	0.32	0.35	0.83	0.78	0.49	0.69	0.53	0.39	0.40	0.48	0.37	0.36		
CHRYSE	0.28	0.27	0.62	0.56	0.45	0.61	0.42	0.31	0.39	0.39	0.26	0.28		
BAANTHR	0.18	0.18	0.45	0.41	0.32	0.47	0.31	0.20	0.24	0.26	0.17	0.18		
BKFLANT	0.20	0.19	0.41	0.28	0.30	0.32	0.20	0.26	0.37	0.33	0.20	0.19		
BKFLANT	0.20	0.15	0.32	0.29	0.21	0.32	0.20	0.27	0.25	0.23	0.20	0.21		
BADPYR	0.17	0.16	0.37	0.33	0.26	0.42	0.25	0.27	0.29	0.29	0.19	0.18		
I123PYR	0.14	0.15	0.29	0.27	0.25	0.31	0.18	0.20	0.23	0.21	0.14	0.14		
DBAHANT	0.045	0.036	0.097	0.068	0.081	0.093	0.052	0.050	0.075	0.071	<0.49	0.045		
B-CHI-PY	0.17	0.12	0.33	0.26	0.26	0.32	0.20	0.21	0.29	0.26	0.16	0.16		
2MENAPH	0.049	0.030	0.090	0.10	0.082	0.074	0.061	<0.47	0.064	0.048	<0.49	0.056		
2FUBP-S	57.4#	59.1#	67.4#	67.0#	62.2#	67.5#	66.3#	53.0#	56.2#	57.8#	73.9#	68.1#		

Table 3. Toledo Harbor CDF Cell 1 PCB Concentrations 1994-1995 (mg/kg)

[illegible]

Table 4. Toledo Harbor CDF Cell 1 Metal Concentrations 1994-1995 (mg/kg).

Parameters	94		95		94		95		94		95		94		94		94	
	Site 1 0'-4'	Site 1 4'-8'	Site 1 8'-12'	Site 1 12'-16'	Site 1 16'-20'	Site 1 20'-24'	Site 1 24'-28'	Site 1 28'-32'	Site 1 32'-36'	Site 1 36'-40'	Site 1 40'-44'	Site 1 44'-48'	Site 1 48'-52'	Site 1 52'-56'	Site 2 0'-4'	Site 2 4'-8'	Site 2 8'-12'	Site 3 0'-4'
Arsenic	8.16	8.20	9.19	8.77	9.34	7.37	6.92	8.08	8.14	8.38	7.52	8.11						
Cadmium	1.30	1.40	2.50	1.70	1.80	2.40	1.50	1.40	2.00	1.60	1.10	1.30						
Chromium	35.90	33.20	53.50	43.60	42.60	36.00	27.10	33.60	40.40	39.20	29.90	31.20						
Copper	35.80	35.70	47.20	41.50	41.20	36.70	28.50	36.20	42.00	39.00	34.50	35.00						
Lead	41.60	41.20	55.80	55.50	46.30	41.40	34.10	40.40	47.70	42.10	33.30	33.30						
Mercury	1.74	1.78	2.26	2.49	1.94	2.28	2.30	2.20	2.46	1.76	3.06	3.06						
Nickel	34.70	35.90	42.50	41.10	38.80	33.20	27.70	35.20	38.40	36.40	33.60	33.20						
Zinc	189.00	171.00	193.00	234.00	159.00	127.00	96.20	164.00	192.00	159.00	159.00	169.00						

Five-4.2 cm x 8.22 cm x 1.02 plastic trays lined with a sheet of plastic were used for seed germination. Each blend was added separately to each tray to a depth of approximately 5.08 cm (2 inches). Three rows of 10 tomato seeds, 10 vinca seeds, 10 marigold seeds, and 20 ryegrass seeds were planted in the same tray containing the different manufactured soil blends. All trays were watered when necessary and seeds allowed to germinate in the greenhouse under lights. Emerged seedlings were counted after 14 and 21 days to determine mean germination percentages.

A seven-week growth test, using manufactured soil blends similarly to those used in the seed germination test, was conducted concurrently with the seed germination test. Eighty 10-cm pots with 10-cm saucers were used to evaluate the growth and appearance of the developing plants in the different blends. All 10-cm pots were prepared by placing a number 42 Whatman™ filter paper in the bottom of each pot to prevent the lost of soil. Each blend was then added separately to each prepared 10-cm pot, to approximately 1.27 cm from the rim. Three tomato seeds, 3 marigold seeds, 3 vinca seeds, and 20 ryegrass seeds were added separately to each blend. Table 5 shows the experimental design used in the bioassay tests.

All pots and trays were randomly placed on tables in the greenhouse under lights providing a day length of 16 hours. Lights were arranged in a pattern of alternating high pressure sodium lamp and a high pressure multi-vapor halide lamp. Alternating the lamps provided an even photosynthetic active radiation (PAR) distribution pattern of 1200 uEinstein/m²/sec. The temperature in the greenhouse was maintained at 32.2 +/-5°C during the day and 21.1 +/-5°C minimum at night. Relative humidity was maintained as close to 100% as possible, but never less than 50%.

Plants were thinned to one plant per pot, when more than one seed germinated in a pot, except the ryegrass pots that were not thinned. In rare instances where no seeds germinated in pots, plant seedlings were removed from the germination trays or another 10-cm pot having more than one plant and transplanted to the pot of a corresponding manufacture soil blend. Plant seedlings were then allowed to grow and develop to evaluate plant growth and appearances. After seven weeks, plants were observed, photographed and harvested from the various blends. The plant material was cut and washed to remove any soil particles and then blotted to remove excess water. The plant material was bagged, dried, and weighed to determine biomass.

Table 5. Toledo Harbor bioassay tests experimental design.

TREATMENTS

Blend 1: Toledo Harbor dredged material
Blend 2: Toledo Harbor dredged material + Cellulose + Biosolids
Blend 3: Toledo Harbor dredged material + Cellulose + Biosolids
Blend 4: Toledo Harbor dredged material + Cellulose + Biosolids
Blend 5: Fertile reference control

PLANT SPECIES

1. Tomatoes (Big Boy)
2. Marigold
3. Ryegrass (Gulf Annual)
4. Vinca

EXPERIMENTAL DESIGN

Seed Germination Test

5 TREATMENTS x 4 SPECIES x 3 REPLICATES split-plot design
5 flats x 4 species x 3 replicates

Growth Test

5 TREATMENTS x 4 SPECIES x 4 REPLICATES completely randomized block design
5 x 4 x 4 = 80 pots (10-cm pots)

STATISTICAL ANALYSIS

Experimental data were analyzed using analyses of variance (ANOVA) procedures of the Statistical Analysis System (SAS Institute, Inc. 1994). Tests of normality were performed using the Shapiro-Wilf statistic: homogeneity of variance was evaluated using the Levene's Test. Comparisons of means were performed using the Duncan's Multiple Range Test. In this report statements of statistical significance without specific indication of probability level refer to $P < 0.05$.

RESULTS AND DISCUSSION

Sediment Characterization

Tables 1, 2, 3 and 4 show the organic compounds analyzed in sediment samples collected in 1994 and 1995. Even though the soil depth intervals were different from 1994 to 1995, analyses were very similar. These data indicate that storage at 4°C for one year did not effect recovery and analysis for PAHs, PCBs or pesticides from 1994 samples compared to freshly collected 1995 samples from site 1. Consequently, the remaining 1994 soil samples from sites 2 and 3 were analyzed to complete the chemical characterization of the Toledo Harbor dredged material in Cell 1. The results of those analyses showed that all three sites within Cell 1 CDF were very similar (Tables 1, 2, 3 and 4). The manufactured soil using Toledo Harbor cell 1 dredged material should not contain any contaminants that should be of concern and can be used unrestrictedly for any landscaping purpose.

The expected chemical composition of the manufactured soil is shown in Table 6. Total metal concentrations in the manufactured soil will be a fraction of the concentrations allowed for unrestricted land use for land receiving biosolids from reconditioned sewage sludge according to the USEPA's Part 503 regulations guidance (Table 6). Soil fertility analysis and physical characteristics of blend 4 are shown in Table 7.

Seed Germination Bioassay Test

Toledo Harbor Dredged Material Cell 1

Figure 12 shows an overall view of the seed germination study after 14 days and results of the seed germination tests are shown in Table 8. An evaluation of the analysis of variance (ANOVA) indicated that seed germination was influenced by treatment ($P=0.0001$), species ($P=0.0001$), and time ($P=0.01$).

Table 6. Predicted metal concentrations in blend 4 using 0-3' surface layer of dredged material from Toledo Harbor Cell 1 (ppm).

Parameter	Dredged Material from Cell 1	Blend 4	EPA 503 Regulations
Arsenic	8.20	5.00	41.00
Cadmium	1.40	0.84	39.00
Chromium	33.20	19.90	
Copper	35.70	21.40	1500.00
Lead	41.20	24.70	300.00
Mercury	1.78	1.07	17.00
Nickel	35.90	21.50	420.00
Zinc	171.00	102.60	2800.00

Table 7. Soil fertility analysis and physical characterization of blend 4 consisting of dredged material from cell 1.

Parameters	Blend 4	Blend 4
	dredged material + cellulose + biosolids*	dredged material + cellulose + biosolids**
Total Kjeldahl Nitrogen, mg/kg	319.0	157.0
Total Phosphorus, mg/kg	140.86	278.61
Ortho-Phosphate, mg/kg	15.80	4.56
Sulfur, mg/kg	619.50	462.74
Magnesium, mg/kg	210.30	195.15
Sodium, mg/kg	79.84	35.84
Calcium, mg/kg	2867.73	5782.46
Zinc, mg/kg	16.19	10.15
Potassium, mg/kg	260.94	229.84
Organic Matter	21.83	20.00
CEC (Me/100g)	57.7	56.8
pH	7.22	8.42
Base Saturation % (Ca-Mg-K-Acid)	84-10-4-2	93-5-2-0
Particle Size		
Sand %	18.90	
Silt %	58.98	
Clay %	22.12	

* prior to plant growth test

**After the plant growth test

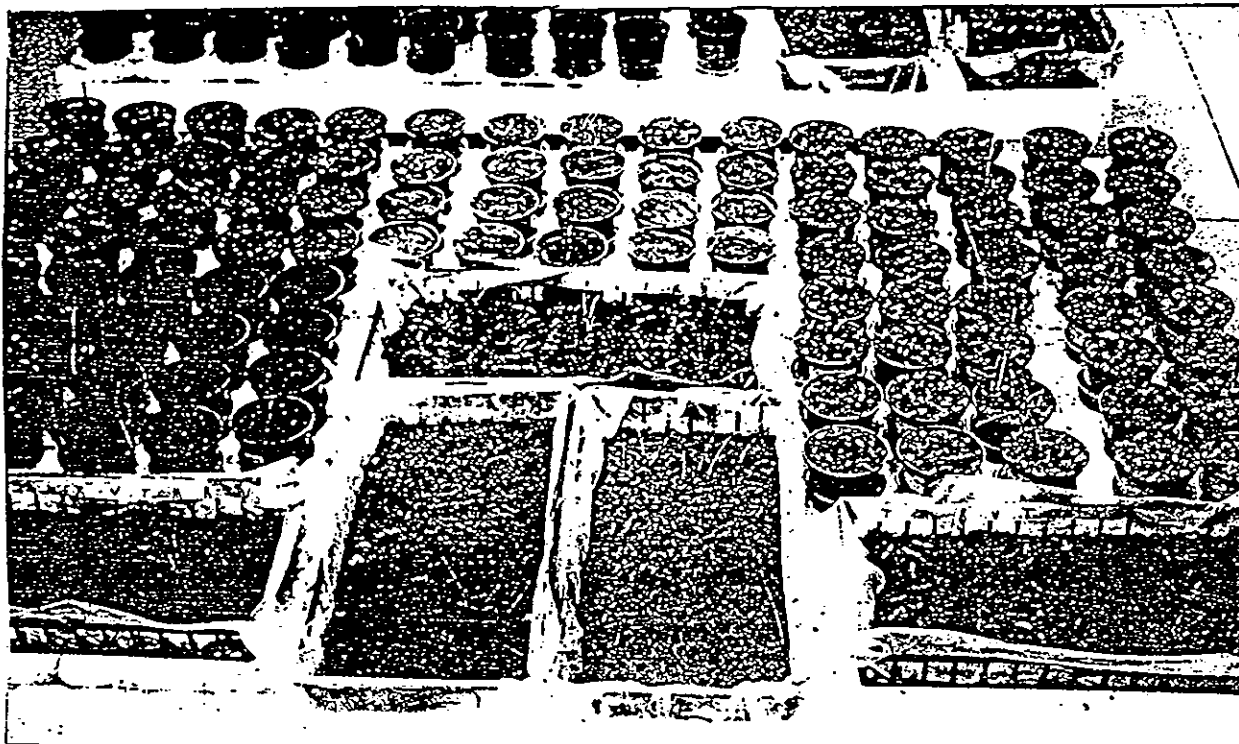


Figure 12. Overall view of the Toledo Harbor seed germination test.

There was also a treatment-species interaction ($P=0.0001$). Generally, the best seed germination was observed in blend 2 consisting of dredged material from Cell 1, cellulose, and biosolids ($P<0.05$) (Table 8). Even though blend 2 showed the best percent germination overall, ryegrass percent seed germination in blends 3 and 1 was significantly higher ($P<0.05$). Seed germination was higher ($P<0.05$) in blend 5 (fertile reference soil) than the other blends (Table 8). For example, tomatoes seed germination was 77% in blend 2 compared to 83% in blend 5, while Marigolds seed germination was 77% in blend 2 compared to 93% in blend 5. Seed germination was in the order of ryegrass > marigold > tomato > vinca. Only 3% of Vinca seeds germinated in blend 2

compared to 40% in blend 5.

Results after 21 days paralleled results obtained in the 14-day seed germination test. The additional time did, however, significantly enhance germination ($P < 0.05$). For example, in blend 2 after 21 days tomato showed a 10% increase in germination, marigold showed an increase of 16%, ryegrass increased 7%, and vinca had the largest increase of 20%. Ryegrass seed germination in blends 3 and 1 also increased 5% and 9%, respectively. Germination percentages in blends 1 and 4 did not differ significantly. The movement of water from sediment to seeds followed by uptake is essential for seed germination. Therefore, the difference observed in seed germination among the different blends could be due to factors affecting the rate and extent of water movement from the manufactured soil blend to the seeds. For example, blends containing the higher percentages of dredged material showed significantly lower seed germination (Table 8). This may be ascribed to the high degree of soil compaction or bulk density of the dredged material.

Dredged material with its high bulk density decrease capillary water and vapor movement of water toward the seed, which in turn could result in decreased imbibition or physically restrict the swelling of the seed, thus possibly impeding seed germination (Hagon and Chan 1997). High bulk density decreases soil aeration, which may also impede seed germination. This additional time allowed the seed to imbibe water and swell, bursting the seed coat, thereby allowing the seeds to germinate. Ryegrass seed germination was significantly higher than other plant species. This suggests that ryegrass seed may be more efficient in taking up water. In addition, it may also show that ryegrass seed may be able to complete germination at lower water contents than tomato, marigold, and vinca.

Plant Growth Bioassay Test

Toledo Harbor Dredged Material Cell 1

Figure 13 shows an overall view of the greenhouse growth test at seven weeks. Visual observations as to leaf color, size, and shape as well as total above-ground biomass were used to evaluate the effects of the different Toledo Harbor dredged material Cell 1 blends on plant growth. Total above-ground biomass was influenced by treatment ($P=0.0001$), and species ($P=0.0001$). There was also a treatment-species interaction effect on total aboveground biomass ($P=0.0001$). An evaluation of the total above-ground biomass revealed that the best plant growth overall was in blend 4 consisting of dredged material from cell 1, cellulose and biosolids ($P<0.05$) (Figures 14a, 14b, 14c and 14d).

All plant species in blend 4 grew better than plants in blends 2, and 3 or 1 (Figures 14a, 14b, 14c and 14d). For example, tomato plants growing in blend 4 had a significantly higher above-ground value than the biomass value obtained from blends 2 and 3 (Figures 14a and 15). Blend 4 vegetated with tomatoes obtained a final total above-ground biomass of 1.01 grams compared to 0.09 grams in blend 2, and 0.58 grams in blend 3 (Table 9). It is also important to note, that there was no significant difference between total above-ground biomass obtained from blend 4 and the total above-ground biomass from blend 5 the fertile reference soil (Figures 15, 16, 17, and 18). Tomatoes above-ground biomass from blend 4 was 1.01 grams compared to 0.95 grams in blend 5 the fertile reference soil (Table 9). Marigold grown in blend 4 had a total above-ground oven-dry biomass of 0.66 grams compared to 0.67 grams in blend 5 (Table 9). Even though overall plant aboveground biomass obtained from blend 4 for all plants was significantly higher than the other blends, ryegrass biomass obtained from blend 3 was not significantly



Figure 13. Overall view of the Toledo Harbor dredged material plant growth test at 7 weeks.

different than biomass obtained from blend 4. Total above-ground biomass for ryegrass from blend 4 was 2.5 grams compared to 1.7 grams, which was better than blend 5, but not different than blend 3, which was 2.27 g (Table 9) (Figures 14c and 17). Vinca total above-ground biomass from blend 4 was 0.02 grams compared to 0.04 grams from blend 5 (Figures 14d and 18).

Visual observations, during the first 2 weeks, of leaf color, size, and shape revealed similarities between plants growing in blend 4 and those growing in blend 5 the fertile reference soil. However, at day 21, plant growth in blend 4 seemed slower than blend 5. Leaf color gradually changed from green to yellow and they were not as broad as plants growing in blend 5. Yellow color and narrow leaves were ascribed to nutrient deficiency in the manufactured soil blend. On day 22, soluble ammonium-nitrate and Miracle™ growth (13N-13P-13K) were added to all of the Toledo Harbor dredged

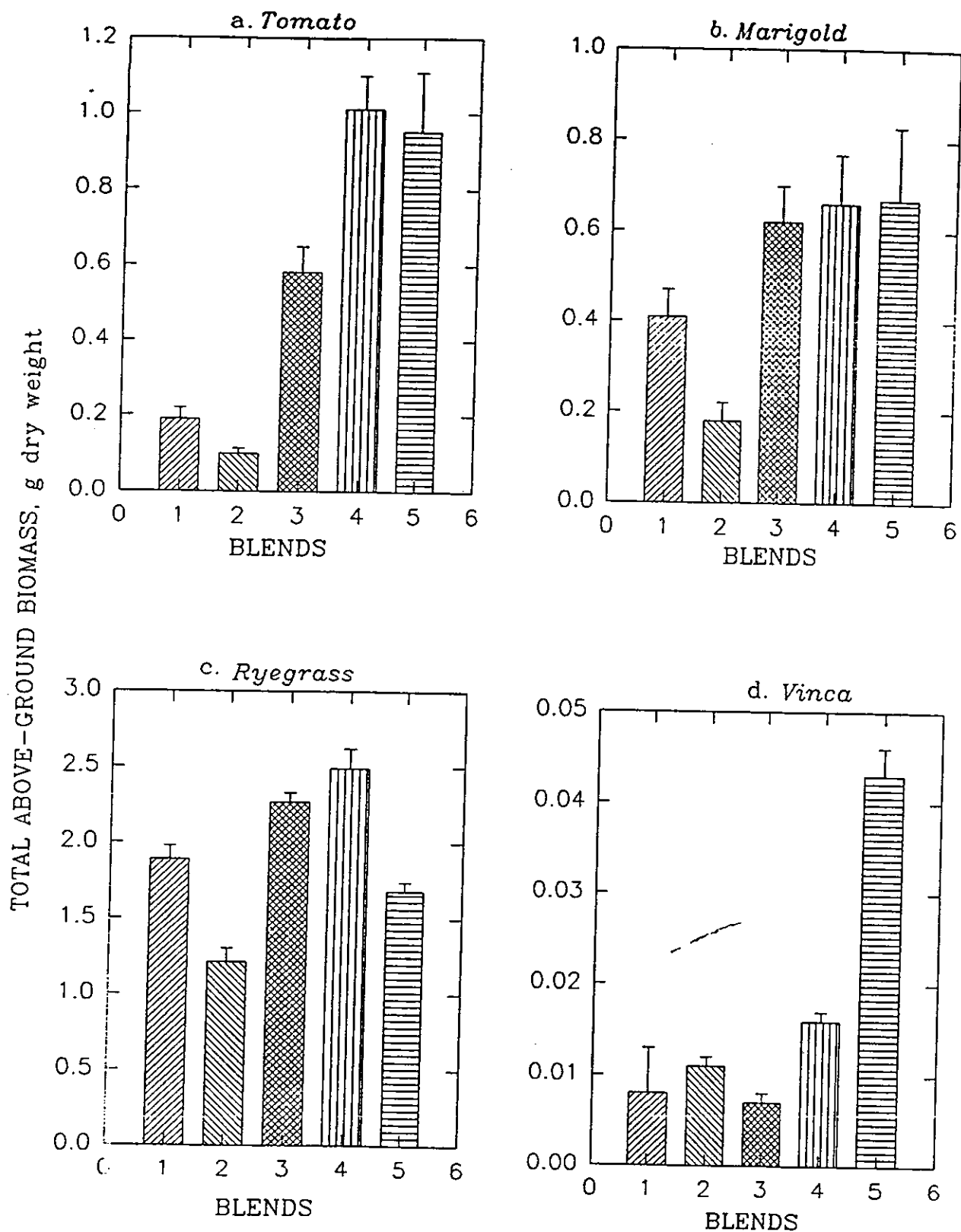


Figure 14. Total above-ground plant biomass from the various Toledo Harbor dredged material blends

material blends. The addition of nutrients to the mixtures appeared to have enhanced plant growth. At the end of 7 weeks, visual observations of leaf color, size, and shape revealed similarities between plant species growing in blend 4 and plant species growing in blend 5 the fertile reference soil (Figures 15, 16, 17, and 18).

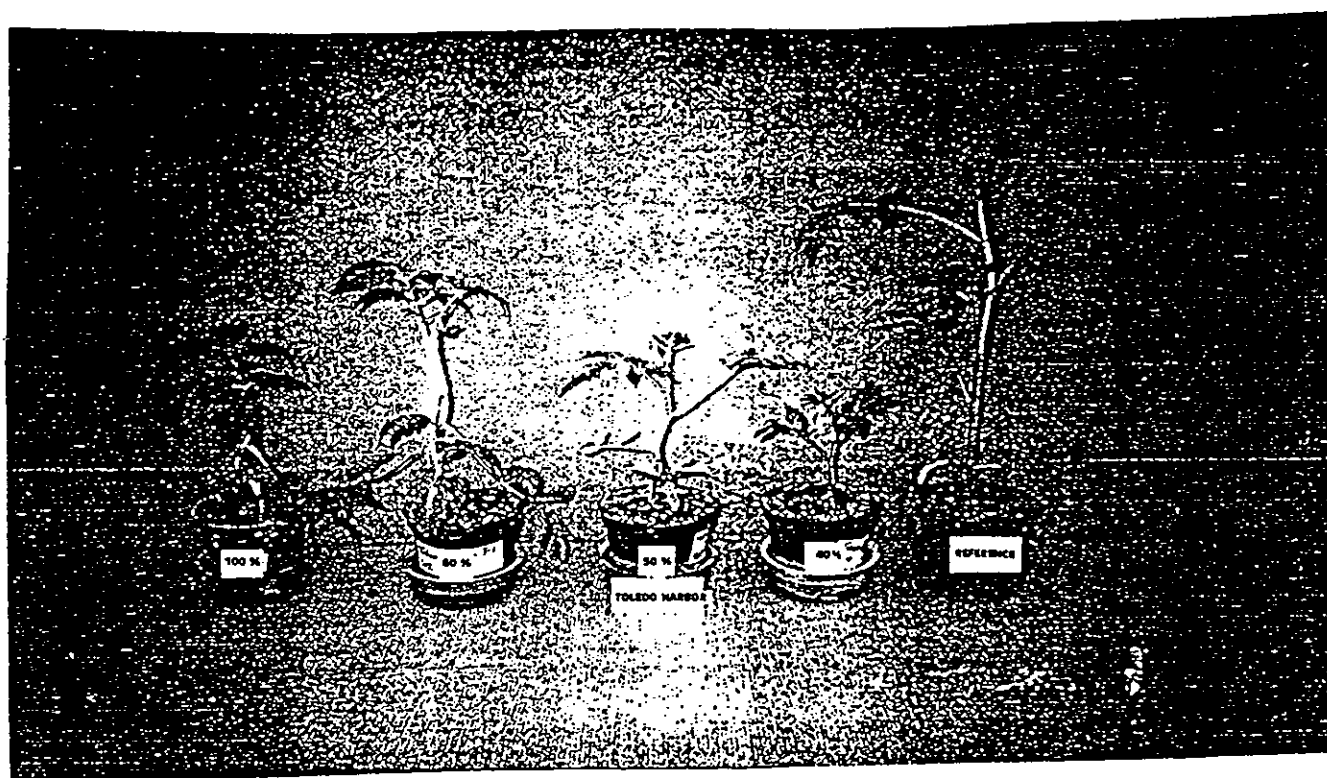


Figure 15. Tomato plants in the various Toledo Harbor dredged material blends at 7 weeks.

Table 8. Percent seed germination for Toledo Harbor dredged material manufactured soil test (percent + S.E.)

Blends	Tomato		Marigold		Ryegrass		Vinca	
	14 d	21 d	14 d	21 d	14 d	21 d	14 d	21 d
5	83.3+/-2.4	86.7+/-2.4	93.3+/-2.3	93.3+/-2.3	91.7+/-7.1	91.7+/-1.2	40.0+/-7.1	60.0+/-8.2
2	76.7+/-8.5	86.7+/-2.4	76.7+/-13.1	93.3+/-2.4	80.0+/-0.0	86.7+/-3.1	3.3+/-2.3	23.3+/-10.3
3	10.0+/-4.1	26.7+/-6.2	63.3+/-8.5	76.7+/-13.1	86.7+/-1.2	91.7+/-1.2	3.3+/-2.3	3.3+/-2.3
4	6.7+/-2.4	10.0+/-4.1	26.7+/-2.4	30.0+/-4.1	68.3+/-9.4	70.0+/-0.0	0.0+/-0.0	0.0+/-0.0
1	0.0+/-0.0	13.3+/-4.7	6.7+/-4.7	10.0+/-7.1	80.0+/-10.8	90.7+/-7.1	0.0+/-0.0	3.3+/-3.3

Table 9. Above-ground biomass from the Toledo Harbor dredged material manufactured soil Test (g).

Blends	Tomato		Marigold		Ryegrass		Vinca	
	Fresh wt.	Dry wt.	Fresh wt.	Dry wt.	Fresh wt.	Dry wt.	Fresh wt.	Dry wt.
5	13.74	0.95	6.62	0.67	15.25	1.68	0.35	0.04
2	1.13	0.09	1.63	0.18	10.13	1.21	0.08	0.02
3	6.46	0.58	6.50	0.61	20.26	2.27	0.17	0.01
4	11.47	1.01	6.10	0.66	21.14	2.50	0.17	0.02
1	2.27	0.19	3.53	0.41	16.52	1.89	0.07	0.01

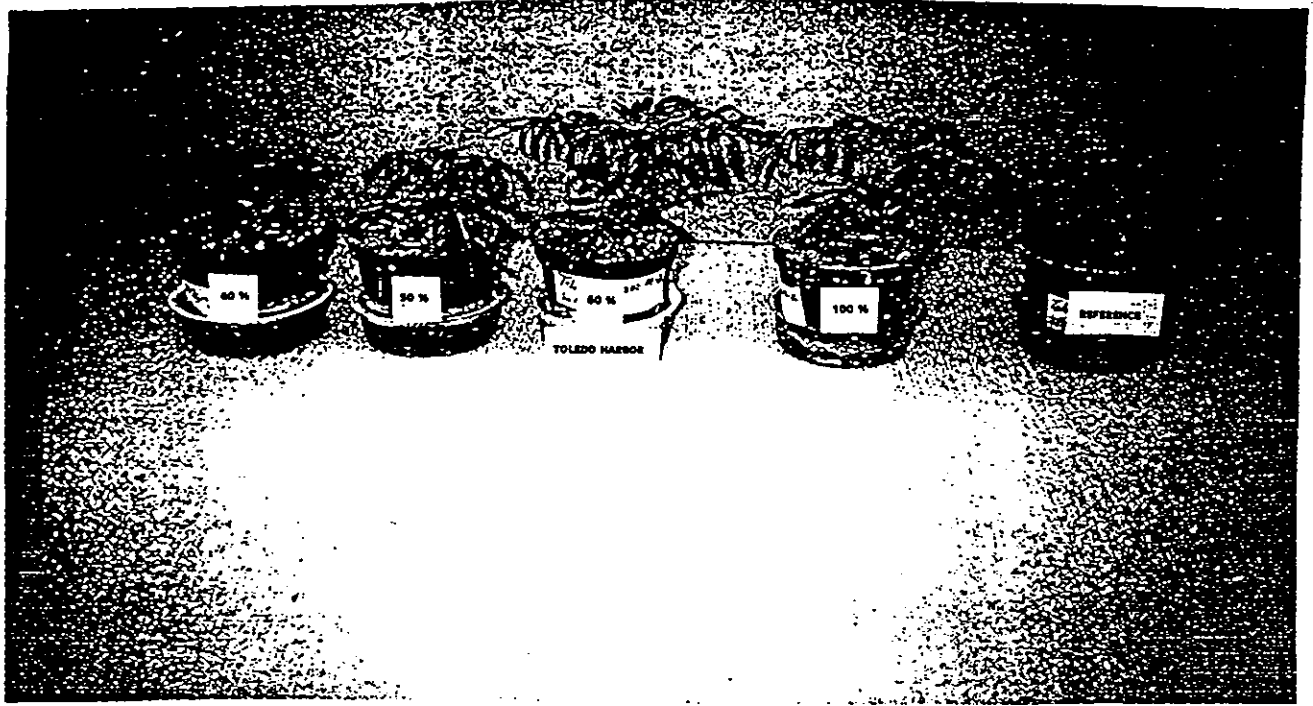


Figure 16. Marigold plants in the various Toledo Harbor dredged material blends at 7 weeks.

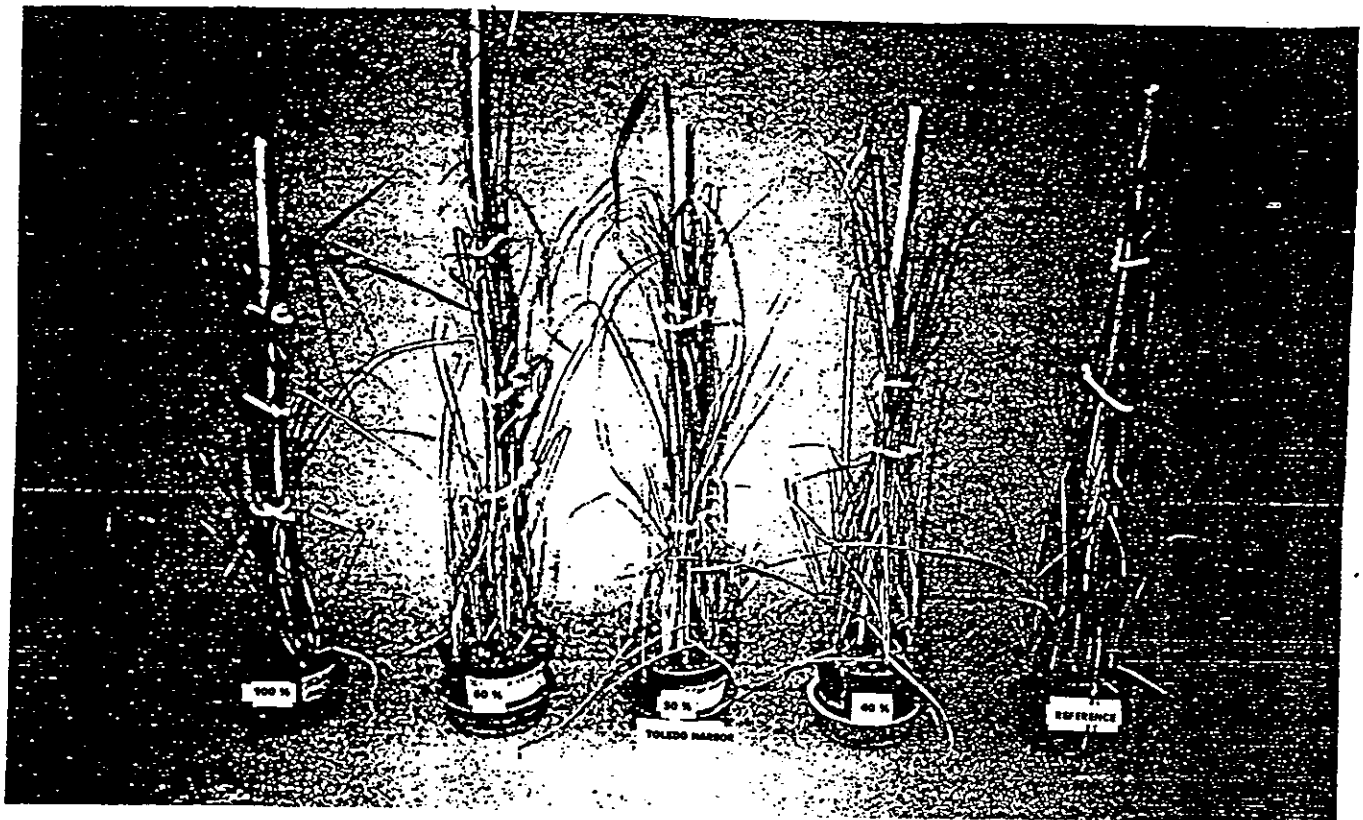


Figure 17. Ryegrass plants in the various Toledo Harbor dredged material blends at 7 weeks.



Figure 18. Vinca plants in the various Toledo Harbor dredged material blends at 7 weeks.

CONCLUSIONS

The results from bioassay tests at the USACE WES indicated that blend 4 consisting of Toledo Harbor dredged material from cell 1, cellulose and biosolids will enhance plant growth. Blend 4 looks very promising as a manufactured soil product that may be used for landscaping and topsoil. The results from Scott and Sons screening test (Appendix A) also showed that Toledo Harbor dredged material from Cell 1 may be used as an ingredient for Scott and Sons Company bagged soil product. Therefore, it is concluded that a high quality manufactured soil product could be blended using Toledo Harbor dredged material from cell 1.

RECOMMENDATIONS

It is recommended that the manufactured soil product containing Toledo Harbor dredged material from Cell 1, cellulose, and biosolids be demonstrated in the field at Toledo, OH. Interested parties who are willing to cooperate in such a demonstration should be contacted such as the City of Toledo, local Garden Clubs, Girl Scouts, Boy Scouts and secondary schools. A demonstration of the use of manufactured soil is recommended for the summer of 1996. Following a successful demonstration, the USACE Buffalo District can advertise for bids by interested companies who want to use dredged material from Cell 1 as an ingredient for manufacturing soil.

LITERATURE CITED

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Aust. J. Biol. Sci. 17:86-89.

APPENDIX A: SUMMARY OF RESULTS FROM SCOTT AND SONS
SCREENING TEST

Table A1. Results from Scott and Sons screening test.

TREATMENT		Seed Germination Test						Plant Growth Test								
		GERMINATION %			QUALITY (1 TO 10)			COLOR (1 TO 10)			QUALITY (1 TO 10)			FRESH WT (g)		
		Rye	Marigold	Tomato	Rye	Marigold	Tomato	Tomato	Marigold	Vinca	Tomato	Marigold	Vinca	Tomato	Marigold	Vinca
10% RM	90% PS	83	85	75	6.0	5.0	5.0	6.8	6.8	3.4	6.8	5.6	3.2	10.61	5.54	0.31
25% RM	75% PS	75	70	80	5.0	4.5	4.5	7.0	6.6	2.6	6.8	5.6	2.0	10.63	5.00	0.20
50% RM	50% PS	88	90	75	7.0	5.5	6.0	5.8	6.2	4.0	6.0	6.4	3.2	11.59	7.77	0.27
100% RM		90	85	80	5.5	5.0	5.0	5.8	6.0	5.0	5.2	5.4	3.6	9.45	5.29	0.40
100% PS		88	80	80	6.5	6.0	5.5	7.0	7.2	4.4	5.8	6.0	4.4	7.36	4.86	0.42

Bold values are equal to or greater than control reference (100% PS).